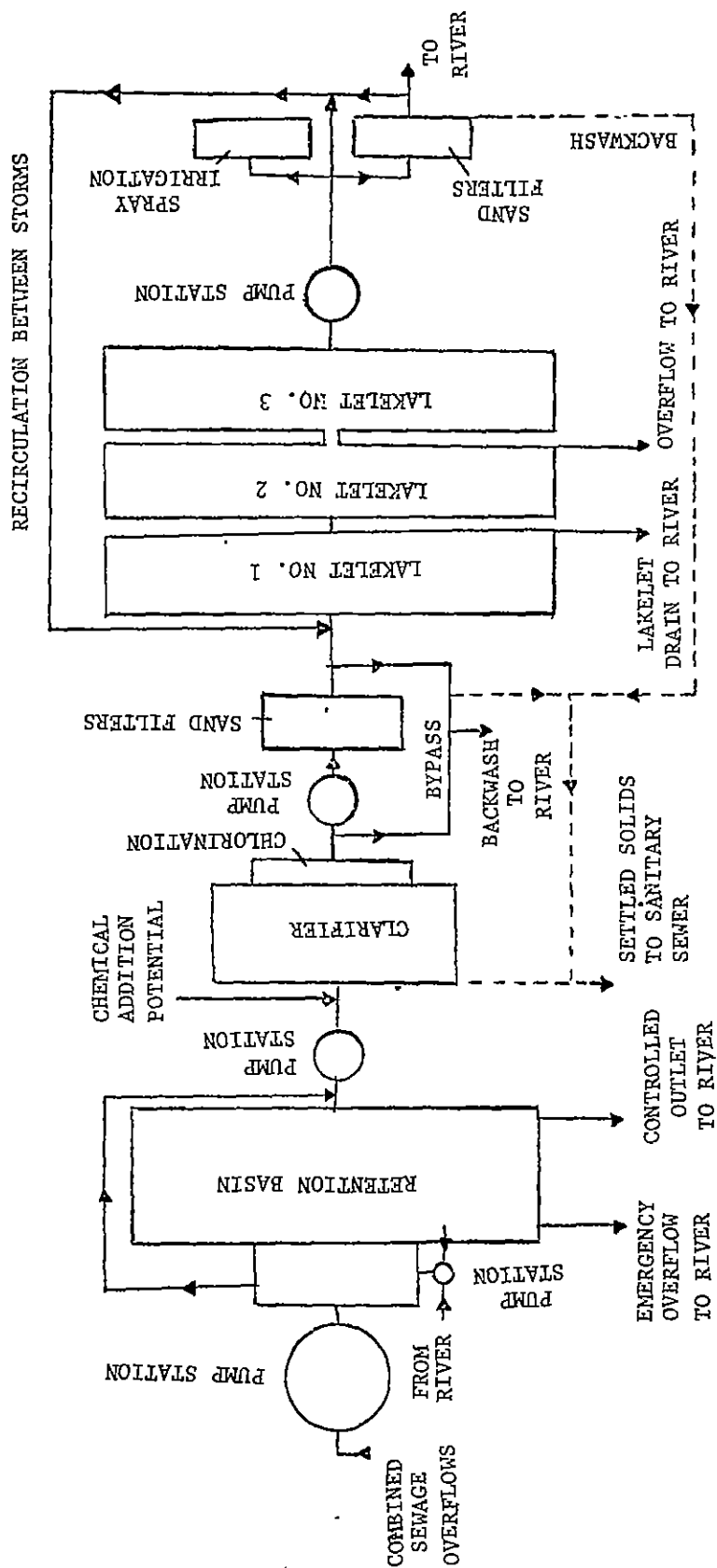


Figure 18.

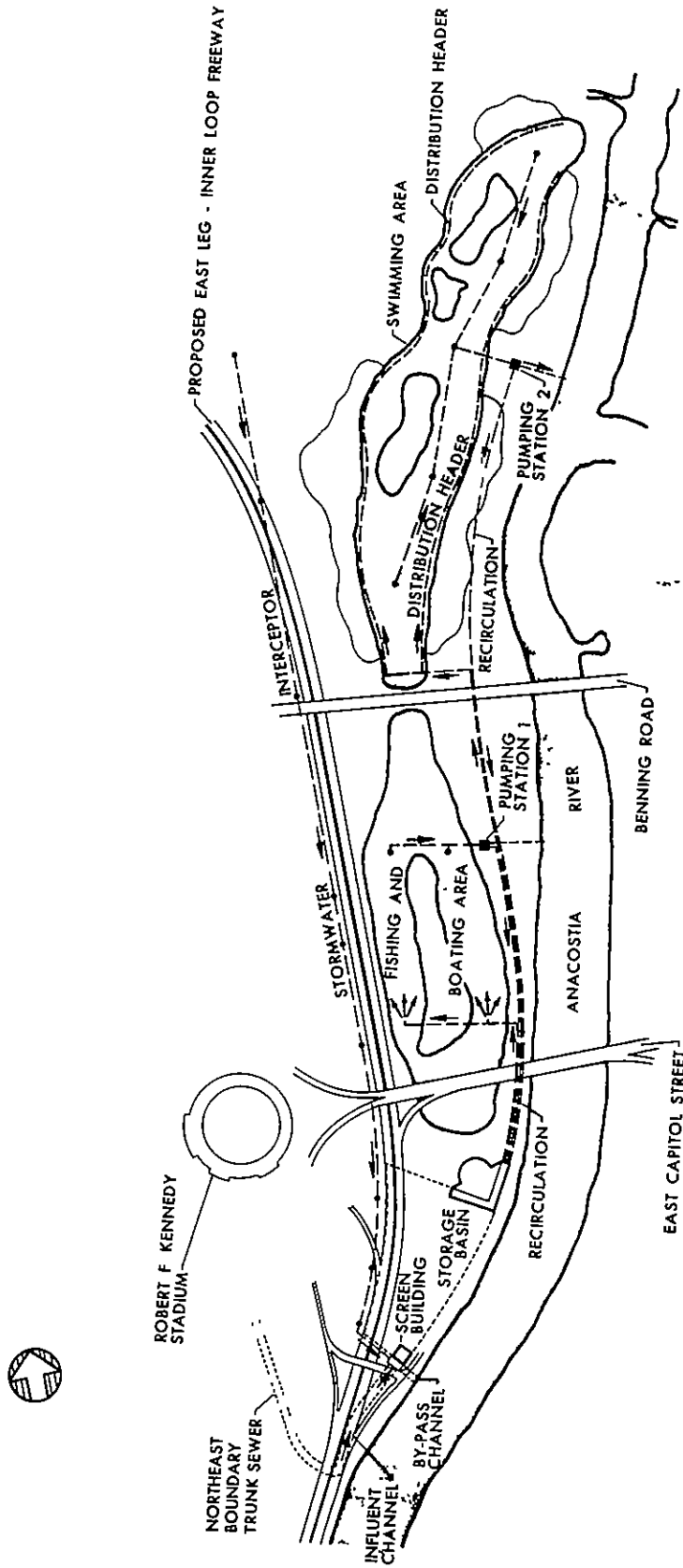
Preliminary Flow Diagram, Combined Sewer-Overflow Control/Treatment System, Lancaster, Pa.



## RETENTION AND TREATMENT FACILITIES Mount Clemens, Michigan

Figure 19

**FEDERAL WATER QUALITY ADMINISTRATION**  
**KINGMAN LAKE PROJECT**  
**WATER RECLAMATION FACILITY**  
**PLOT PLAN**



**FIGURE 20**

Our Program, in conjunction with APWA, has refined and is demonstrating the swirl flow regulator/solids-liquid separator (Figure 21). The device is of simple annular-shaped construction requiring no moving parts. It provides a dual function, regulating flow by a central circular weir, while simultaneously treating combined sewage by swirl action which imparts liquid-solids separation. The low-flow concentrate is diverted to the sanitary sewerage system, and the relatively clear liquid overflows the weir into a downshaft and receives further treatment or is discharged to the stream. This device is capable of functioning effectively over a wide range of combined sewer overflow rates having the ability to effectively separate settleable and light-weight organic suspended matter at a small fraction of the detention time required for conventional sedimentation. For these reasons serious thought is now being given to the use of swirl units in series and in parallel solely as wet-weather treatment plant systems. A helical or spiral type regulator/separator has also been developed based on similar principles as the swirl device, and we are looking for further refinement. Mr. Richard Sullivan will speak on this subject following my presentation.

#### Flow Measurement

The quantitative and qualitative measurement of storm overflows is essential for process design, control, and evaluation. The "urban intelligence systems" previously mentioned require real-time data from rapid, remote sensors in order to achieve remote control of a sewerage network. Conventional flow meters have not been developed for the highly-varying surges encountered in combined sewers. Here, a measuring device may be subjected to very low flow rates, submergence, reverse flow, and surcharge, all during a single rainstorm. These severe flow conditions rule out the reliable and accurate application of conventional devices, such as weirs and flumes at many

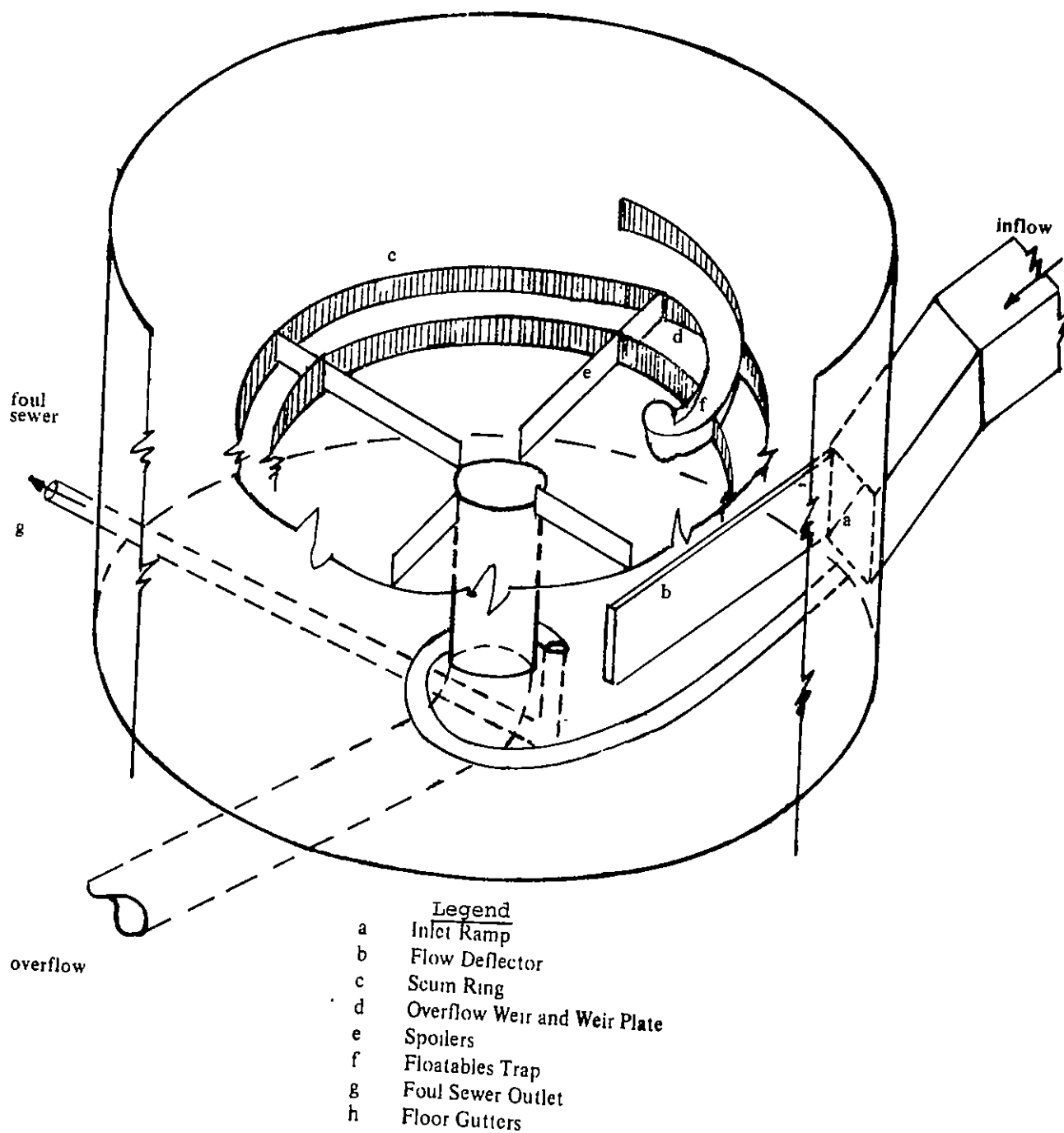


Figure 21  
Isometric View of Swirl Regulator/Concentrator

locations. Consequently, we are deeply involved in the development and demonstration of sophisticated and new flow measuring equipment utilizing the various principles of: hot-film anemometers, concentration of induced foreign matter, ultrasound, and electromagnetics as applied to open channel flow.

Our Program has also contributed towards the development of a prototype monitor capable of instantaneous, in-situ measurement of suspended solids based on the optical principle of light depolarization.

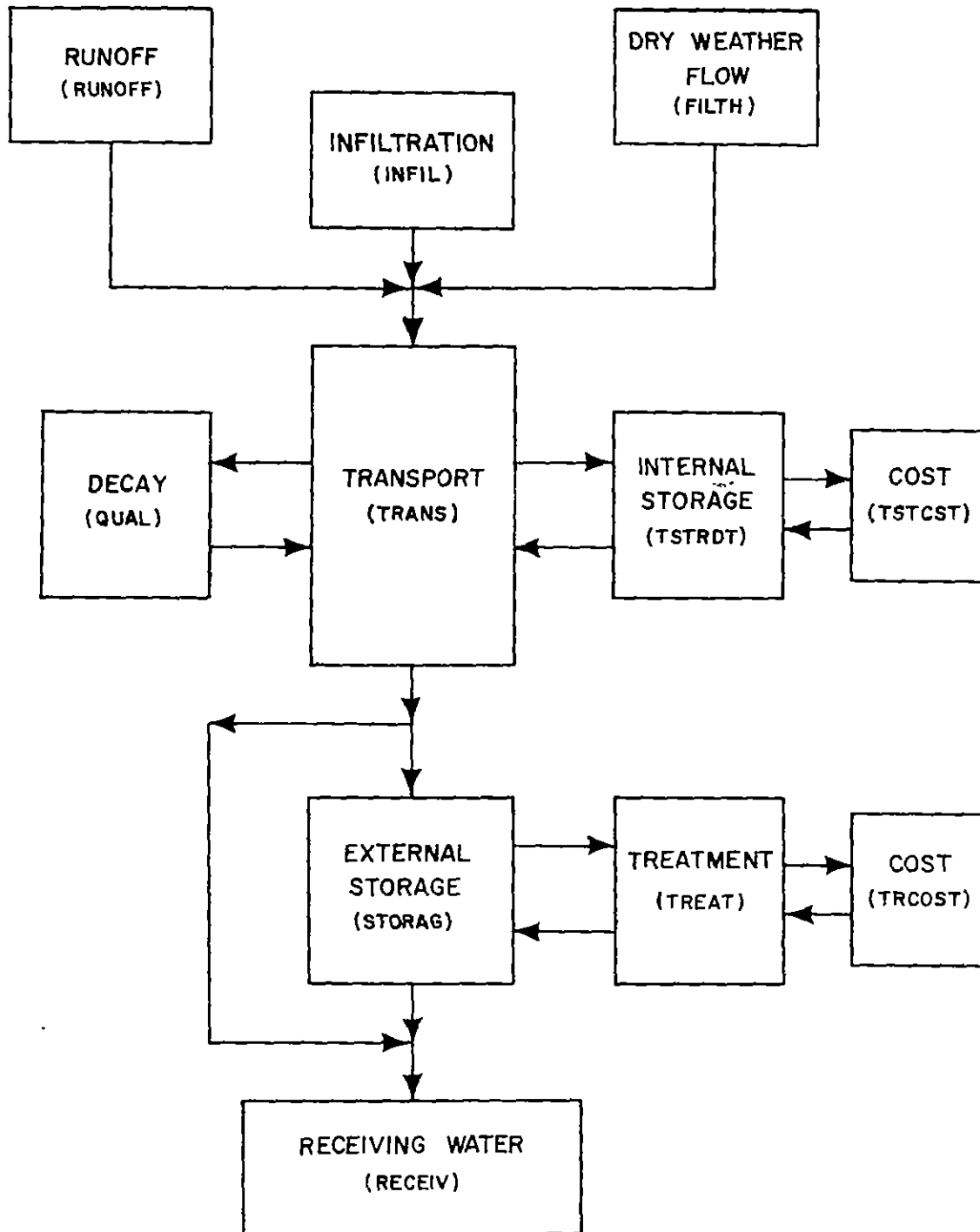
#### USEPA Stormwater Management Model (SWMM)

The capability to analyse various component flows and pollution loads throughout a sewerage system is one of the keys to better design of control and treatment systems. Due to complexities of the rainfall-runoff-flow phenomena past analyses have been less than adequate, resulting in poor estimates of flow and predicted system responses to a storm. By virtue of previous undertakings, we now have available an operational "descriptive" mathematical model which can overcome former analytical deficiencies. Figure 22 depicts a schematic overview of the model.

We are now in the initial phase of demonstrating the application of this method for "decision-making", that is, its ability to analyse a major combined sewer system to select and to design control and treatment approaches based on cost/effectiveness and to eventually design a computerized means of overall management of the system during storm flows. The model will be fully explained later on today by Dr. Wayne Huber.

#### PROGRAM PROJECT NEEDS

Looking ahead, the Storm and Combined Sewer Pollution Control Program



Note: Subroutine names are shown in parentheses.

Figure 22. OVERVIEW OF MODEL STRUCTURE

needs are vast and numerous. At present, we are directing our efforts to the following:

1. A nation-wide assessment of sewerage and non-sewerage straight urban runoff impacts, not combined sewerage - a consideration which has been stressed by the 1972 Amendments to the FWPCA Act.
2. Dual use facilities for wet-weather and dry-weather treatment. Wet-weather facilities built in conjunction with new or existing sanitary plants can demonstrate their synergistic benefit by being utilized to take over during repairs, polishing secondary effluents, or increasing dry-weather treatment capacity during the vast majority of the time, i.e., when it is not raining.
3. Land development making full use of runoff and natural drainage - aesthetically blending into the surrounding environment rather than upsetting it.
4. Wet-weather facilities for treatment of dry-weather creek flow, again making full use of these facilities during otherwise downtime.
5. A stormwater model monitoring/management system for dissemination, updating, and instructions on model application.
6. A functional evaluation of the need for catch basins today - and development of new alternatives.
7. Establishment of uniform techniques for sampling and analysis of storm flow and for determining design volumes and flowrates.
8. Further development of flow measuring devices.
9. Fostering a stormwater survey course at the university graduate level. Storm generated pollution ranks high along with domestic and industrial sources and yet remains unstressed in the schools. With wet-weather control requirements evident, now is the time to encourage universities to cover the concepts of stormwater runoff and combined sewer overflow pollution in proper perspective in their graduate school water pollution

control curriculum.

10. The swirl device applied for grit removal and primary separation of solids from combined sewage, stormwater, erosion runoff, along with the optimization of its sister device, the helical flow regulator/solids separator.

There are also certain major control methods requiring further development. "Upstream" storage or other control processes to decrease the stormwater runoff effect on lower portions of the system is one case in point. Aside from the main objective of controlling storm-generated pollution, upstream control can preclude the need for additional downstream sewer line capacity and associated construction requirements, alleviate shock loadings due to scouring velocities, relieve the often occurring expense of constructing facilities downstream near watercourses in unstable soil with high water table, while offering greater flexibility for control and treatment. An example of this would be the temporary storage or attenuation of stormwater at the building or immediate area through the use of holding tanks, seepage pits (possibly for recharge), roof tops, parks and playgrounds, backyard detention facilities, porous pavement (previously discussed) or neighborhood decentralized stormwater collection sumps including storage facilities under streets. Upstream control systems should automatically regulate discharge from storage to the groundwater, a watercourse, or a sewer system. Plans for reuse of stored water for irrigation, street cleaning, sewer flushing, aesthetic and recreational ponds, potable supply, and other purposes is also encouraged.

Many more ideas and concepts could be added - some may be more significant than those discussed. Submission of ideas, project proposals or grant applications to the USEPA is strongly encouraged.

## CONCLUSION

All facts point to a real requirement for treating and controlling stormwater runoff and combined sewer overflows. In view of the tremendous quantities of pollutants bypassed during rainfall from the combined sewer system, it does not seem reasonable to debate whether secondary treatment plants should be designed for 80, 85, or 90% BOD or suspended solids removal, when in fact the small increments gained in this range are completely overshadowed by the bypassing occurring at regulators during wet-weather flow.

The multi-billion dollar treatment plant upgrading and expansion program now going on throughout the country will do much to alleviate pollution of our waters. However, means of mitigating the effects of combined sewers must also be found if we hope to abate the pollution in an optimal manner. Wet-weather standards are already being instituted by the federal government and some states and localities. Recognizing this, our Program will strive to be a prime support for this real world application.

## SECTION II

### PREVENTION AND CONTROL OF INFILTRATION AND INFLOW

by

Richard H. Sullivan  
Assistant Executive Director  
American Public Works Association

The American Public Works Association has had an active program of research in the field of storm water pollution. Its program has investigated such fields as the pollution of storm water, the extent of combined sewer facilities, the design, operation and maintenance of combined sewer overflow regulators and the prevention and correction of excessive infiltration and inflow into sewers. These projects were either conducted under contract with the U. S. Federal Government or as cost-sharing projects jointly financed by local public agencies and the federal government. My remarks today will be based upon the research findings of our Foundation.

I will briefly review some of the major findings of our report, "Prevention and Control of Infiltration and Inflow". I will also review with you guidelines for the establishment of a survey to determine the nature and extent of infiltration, and some of the factors to be used in making an economic analysis of desirable corrective actions.

In our study of the problems of combined sewer facilities it

became evident that infiltration plays a major role in many facilities by either causing more frequent or prolonged overflow events. With the assistance of some 34 local agencies and the Water Quality Office, we undertook a study of the prevention and correction of infiltration. For ease of discussion we decided to consider the "Two I's" of infiltration. The first "I" - infiltration - is in the classic sense, that flow which enters the sewer through pipe and joint defects and manhole covers, etc., and - inflow - is surface water which is deliberately introduced into the system through footing drains, downspouts, area-way drains, and such. Infiltration and inflow both take up capacity within the collection system. However, the two have entirely different characteristics as to time of occurrence, and means of correction and prevention.

If infiltration and inflow exist, why should we be concerned? One of the most common problems associated with excessive infiltration or inflow is backups into basements, flooding of manholes, treatment plant overloads, pavement and sewer failures; all are common problems. Exfiltration may result in pollution of the groundwater table.

When we look at the extent of infiltration, we can conclude that all sewers are combined, it is all a matter of degree. Where even minimal amounts of infiltration and inflow are present, a regulator device of some type will be used on the sanitary sewer system to relieve the excess flow condition. Quite often this is only a leader from a sanitary sewer to a storm sewer, or a hole in the side of a sanitary sewer manhole which, under surcharge conditions, will allow excess flow to enter a creek or stream bed. For such systems to be described as "separate" is ironic, inasmuch as its volume of non-sanitary flow may reach 40 to 1, as contrasted to the strict combined system where this could be 90 to 100 to 1.

Correction of infiltration problems can be categorized under the dual headings of prevention of infiltration and inflow in new systems and the correction of existing conditions.

With regard to new construction; tremendous advances have been made in pipe and joint materials. Contractors and pipe suppliers who worked with the APWA in the preparation of the report were agreed that a construction standard of 200 gallons per inch-mile per day was reasonable and could be met without additional cost to the local agency. In practice we found that consulting engineers had, in effect, an extremely wide array of construction standards which they regularly cite for new construction. There was little agreement as far as to the unit of measure or how the standard would be applied. In this regard I think it is important to remember the effects of a low standard for gallons per inch per mile applied to lengths of 200, 300 and 500 feet. Allowable infiltration may be almost impossible to measure. Specifications using low infiltration rates should spell out how compliance is to be measured. For example: 200 gallons per inch per mile per day allows 4.4 gallons in an 8-inch pipe an hour between manholes 350 feet apart.

The detection of infiltration is a time consuming and generally expensive process. I am not aware of any short cuts to the preparation of a comprehensive survey. Our report contains an outline of a ten-point program as developed by the American Pipe Services Co. of Minneapolis, Minnesota. For purposes of our discussion today I have expanded this to twelve points, and would like to consider these steps briefly with you.

The steps involved in a complete infiltration-inflow analysis include:

1. SET OBJECTIVES: determine what is the apparent problem, in what condition is the sewer system, is there an adequate

- maintenance program, how can sources of infiltration/inflow be determined, and at what cost.
2. IDENTIFY SYSTEM: prepare plot plan of entire system, identifying component drainage systems and key manholes within the system.
  3. IDENTIFY SCOPE OF INFILTRATION: make flow measurement, install ground water gauges in manholes, and meter flows at lift pumps.
  4. RAINFALL SIMULATION: flood the storm sewer and determine if flow enters the sanitary system - use when infiltration/inflow problems are identified as rain-connected.
  5. DETERMINE EXTENT OF SEWER CLEANING NEEDED: a TV camera is not effective unless a sewer line is very clean.
  6. MAKE AN ECONOMIC & FEASIBILITY STUDY to determine which portions of the system will be cleaned and physically inspected.
  7. CLEAN SEWERS to be inspected.
  8. MAKE TELEVISION INSPECTION.
  9. DETERMINE EXTENT & LOCATION OF INFLOW.
  10. MAKE ECONOMIC ANALYSIS: where should rehabilitation or replacement work be conducted.
  11. RESTORE AND REPAIR SYSTEM.
  12. ESTABLISH TREATMENT PLANT DESIGN CRITERIA on basis of reduced flows.

One of the important points that must be stressed again and again is that if we are going to look for infiltration we must look when it logically will be present. Thus, the use of ground-water gauges to determine whether or not the individual pipe sections are below the groundwater table is a necessity. Second, the sewer lines must be clean if they are to be inspected. By clean, I mean that a full gauge tool must be passed through the line. This is generally more than the normal cleaning procedure of most agen-

cies. The cleaning procedure will be expensive and time consuming. Therefore, careful analysis must be made as to the capability of the agency to clean sewers and this must be attached with the planned progress of the survey. Cleaning may be a deciding factor in determining how much of a system may be actually investigated. It may be necessary to contract for cleaning.

Properly timed television inspection in a well-cleaned sewer is extremely helpful in analyzing the location and amount of infiltration waters entering the sewer line. Data obtained will include an indication as to locations of many sources of inflow and building sewer infiltration. The latter, building sewer infiltration, is a hard problem to approach, inasmuch as it is very difficult to gain access to that portion of the sewer system. A rough analysis of a community's total sewer system may indicate as much as half of the total sewer system is building sewers. Should the groundwater table be high, and the building sewers under the groundwater table, a substantial portion of the total load may come from this portion of the sewer system. Again, such lines if they are shallow may be an important source of infiltration and inflow during periods of precipitation. One community which experienced severe overloading and basement backups during periods of rainfall found that roof leaders discharged adjacent to a building allowed almost a direct connection of the water from the roof into the building sewer. This community required that roof leaders be discharged five feet from the foundation, and the problem was corrected. In other communities official practice may have allowed foundations drains to be connected to the sanitary sewer. This again leads to a tremendous increase in the flow. In a like manner, sump pumps, if allowed to discharge into the sewer system, quickly cause overloading. Yet another source of inflow water is from manholes. There are many conflicting opinions, however, with regard to using watertight covers on manholes because of the buildup of gas within

the system. However, if the manhole is to be located in an area where storm water may enter the system, many communities have gone to watertight covers or have added plugs to the openings to keep storm water out.

Detection of the location of inflow is perhaps the easiest part of the battle. The real test is to attempt to change or correct the conditions within private property. Residents of built-up areas without storm drains in many areas are loathe to have sump pumps discharge onto lawn areas. In fact, in many areas there may not be sufficient lawn area to take the flow. In like manner, foundation drains must have a location and a way of carrying off the flow or there will be backup into the basement. To reduce erosion, roof leaders may be discharged into the sanitary sewer.

The APWA report has recommended that agencies prior to funding reconstruction of paralleling of their interceptor sewer or relief sewer and construction or additional treatment facilities, make a thorough infiltration study to determine the amount of flow which might be eliminated by correction of inflow conditions or improvements of the sewer line to eliminate infiltration.

From a dollars and cents point of view, this seems appropriate. From a standpoint of controlling pollution, we are generally further ahead in eliminating pollution if we clean up the source rather than if we build additional facilities and then have continuing operational cost.

For this reason, in our Manual of Practice, we attempted to develop an outline of an economic analysis in order that the cost of infiltration and inflow waters might be determined and so that an agency could determine how much it could afford to spend for the

control of infiltration and inflow. Very few examples were found where such an economic evaluation had been made. While many of the tools that are available at this time are not exact, because of lack of adequate record systems by local agencies, we must have the economic justification of our pollution control activities.

SECTION III

COMBINED SEWER OVERFLOW REGULATOR FACILITIES

by

Richard H. Sullivan

Assistant Executive Director

American Public Works Association

There is a broad cross-sectional interest in the proper design and operation of combined sewer overflow regulators. Consulting engineers - general design of facilities; pollution control personnel - monitoring facilities to determine the nature and extent of the pollutional load to receiving waters; industrial representatives - to design and build the actual regulator; and local governmental officials - to bridge between these three groups and to pay for the facilities. Payment is very important inasmuch as for this portion of the pollution control program, federal and state aid is not generally available to assist local government in financing the construction and reconstruction of facilities that will lead to a reduction of this source of the pollutional load. Lack of such aid is somewhat unique and, undoubtedly, is directly responsible for the fact that relatively little work has been accomplished at the local level to implement the types of pollution control programs which have been advocated and demonstrated by the Water Quality Office in the field of storm and combined sewers. Construction grant funds from EPA have been available for only a handful of facilities,

where essentially primary treatment will be accomplished.

It is appropriate to consider the "official policy" regarding combined sewers. For many years it appeared that the official policy of the federal government was that combined sewers would be separated. In 1967 the APWA completed its report on the extent of combined sewer facilities with a cost estimate of \$48 billion in 1967 dollars to separating systems involving some 36 million persons. It appears that generally the Washington officials are now convinced that separation alone is not the solution, though the word has not necessarily been reached, or been adopted by the regional offices, as we still see results of conferences which will require separation of combined sewers on a wholesale basis. Other federal agencies such as DOT and HUD have also geared their programs to further the separation of combined sewers. This becomes particularly ironic as the extent of stormwater pollution becomes evident and in some areas we begin to talk or require treatment facilities for stormwater. A great deal of rethinking appears warranted at this time before actually establishing a national policy. From the work that the APWA has accomplished, it has been shown that storm waters are polluted whether or not they are carried in separate or combined sewers and that to meet receiving water quality standards, treatment or control facilities may be necessary.

Consulting engineers and local government officials in considering the combined sewer overflow regulator facility problems should begin by defining their needs, particularly in measurable terms. For instance, a general need is to either reduce or eliminate pollution from combined sewer overflows. The need might be based upon a requirement to improve receiving water quality, to improve the value of land adjacent to the overflow, to improve or make possible operation of treatment or control facilities, or to

improve operation of the treatment plant. The need, then, must be defined in terms of how much or the extent of actual improvement required. Means must be available to determine whether or not the desired goal has been achieved.

If our desire is to reduce pollution, we should determine whether or not the economical solution is to reduce flow in the combined sewer by a system of surface storage, in-system storage or treatment of the overflow. The type and size of the regulator will vary considerably depending upon the nature of the treatment or control device.

Criteria for the operation of the regulator traditionally has been to limit flow to the interceptor. I would like for you to consider, however, the concept of the Two Q's, control of quality and quantity of the overflow. Regulators can be classified as either static or dynamic. If they are static, they perform in a determined manner, and are unresponsive to changes in control levels in the interceptor or changes in the quality of the sewage. Dynamic regulators, on the other hand, can be designed to be responsive to a variety of flow conditions and flow characteristics. The regulator must be responsive to flow both in the interceptor and collector sewer, the maximum pollutional load should be diverted to the interceptor sewer, there should be no dry weather overflows, there should be low maintenance cost, and a low initial cost is desirable. Operation of the regulator must be responsive to changing conditions. Quality of overflow may be improved by screening, use of secondary motion, or the mode of operation. Choice of the individual regulating device to be used will be influenced by space required, availability of access, outflow conditions, head-loss within the regulator, and exterior power requirements. All must be evaluated and considered.

The major findings and recommendations of the APWA study were:

Efforts should be made by local jurisdictions to consolidate minor overflow points into fewer locations, in which the installation and maintenance of sophisticated regulator devices and controls will be economically and physically justified.

"Total systems" management of sewer system regulator-overflow facilities should be instituted wherever this procedure can be shown to be feasible and economical. This will involve the use of dynamic-type regulator devices and the application of instrumentation and automatic-automation control methods which will be expedited by a reduction in the number of overflow points.

Dynamic-type regulators should be used wherever possible and feasible for "traffic control" of combined sewer flows. This could shunt surcharges of portions of such a system into sections of sewers which are not simultaneously so affected. This approach could be enhanced by the monitoring of precipitation and sewer flows through an adequate network of stations, in communication with a central control point from whence flow routing decisions can emanate.

The type of regulator used should be determined on the basis of its performance and potential reduction in overflow pollutional effects.

Maintenance schedules and budgetary appropriations should be planned on the basis of the specific needs of static, dynamic and instrumented units in service. Each type of regulator should be given the attention it requires to achieve maximum

performance.

Regulator facilities should be situated in accessible locations, provided with safe and dependable access facilities, be free of other safety hazards, have adequate space for necessary maintenance work and, when possible, be accessible from locations other than the street or highway right-of-way.

Maintenance crews should be adequately staffed and crews should be provided with all necessary service equipment and tools for their work and for their protection. In-service training should be provided and preventive maintenance schedules should be established. Records of maintenance work must be accurate and complete in order to assess properly the effectiveness of regulator operations and to allocate budget costs for each specific maintenance and operation procedure.

Specifications must require the use of the most servicable corrosion-resistant and moisture and explosion-proof materials in the fabrication and installation of regulator devices and control facilities. The number of movable parts and appurtenances should be reduced as much as possible, commensurate with efforts to provide greater sophistication of regulator facilities.

Where possible, tide gates should be located in adequate chambers. In cases where system control of regulator-overflow networks is provided by automatic-automated means, the proximity of tide gates with regulator chambers will facilitate the tie-in of backwater control with overflow control. State and provincial water pollution control agencies should increase their regulatory control of this source of pollution and provide standard requirements and the engineering personnel

necessary for enforcing the control of overflows from combined sewer systems. Further, such agencies must recognize the fact that existing combined sewer systems must be upgraded if pollution levels are to be reduced.

Efforts should be made to design regulators to minimize clogging and consequent polluttional overflows. Where clogging is inevitable, maintenance schedules should be adapted to correct this condition as expeditiously as possible.

As indicated, interest by various states in regulators and overflow polluttional problems vary considerably. Few states have a staff knowledgeable enough to give much guidance to local officials or to even review plans. Many states appear to want to believe that if they do not get too concerned about the problem, it will go away. Many seem to be taking the textbook advice that combined sewers are a thing of the past. Inasmuch as over 30 million people are directly served by combined sewers with some 18,000 overflow points, I doubt that this represents much more than wishful thinking.

At the close of the research project the APWA developed a Manual of Practice. There is a great deal of heretofore unpublished work in it, which represents good practice in the field. Certainly you and the public agency which you serve should review the Manual for information regarding requirements for the design, operation and maintenance of facilities, as well as a description of some of the newer types of regulating devices. Many of you will have a very difficult time convincing an agency that they should pay more than the \$2,000 to \$4,000 cost of a static regulator device. However, if pollution is to be reduced, time and money spent on the design and construction of adequate regulator facilities will do much to enhance the local program.

SECTION IV

PRESSURE SEWERS

by

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## Introduction

The pressure sewer concept has been around for a number of years. When referring to pressure sewers, we are dealing with a wastewater collection system that utilizes a newly developed Grinder Pump Unit and small diameter plastic or metallic piping systems. It is by no means intended to replace gravity sewers but only to supplement the wastewater collection system.

With financial assistance from both the State and Federal governments, a 13 month study was completed in Albany, New York for the purpose of evaluating the functional specifications of the GP Units and to gain first hand operating experience on the mechanical performance, use pattern, operating cost, maintenance requirements, etc. on these units. The final report is available from the U. S. Government Printing Office<sup>(1)</sup>. A full description of the installations, the monitoring equipment, the piping system, etc. was published previously<sup>(2)</sup>.

Therefore, it is not necessary to go into a detailed description of the installation, with the exception of stating that the pressure sewer system was very simple in design. The wastewater was diverted to the Grinder Pump Unit's tank from which point it was discharged by means of a  $1\frac{1}{4}$ " plastic pipe pressure lateral to an outside  $1\frac{1}{4}$ " to 3" plastic pressure main. The pressure main at a 4 foot depth received the macerated wastewater from all 12 houses and simply discharged it into a gravity system within the city of Albany (Figure 1).

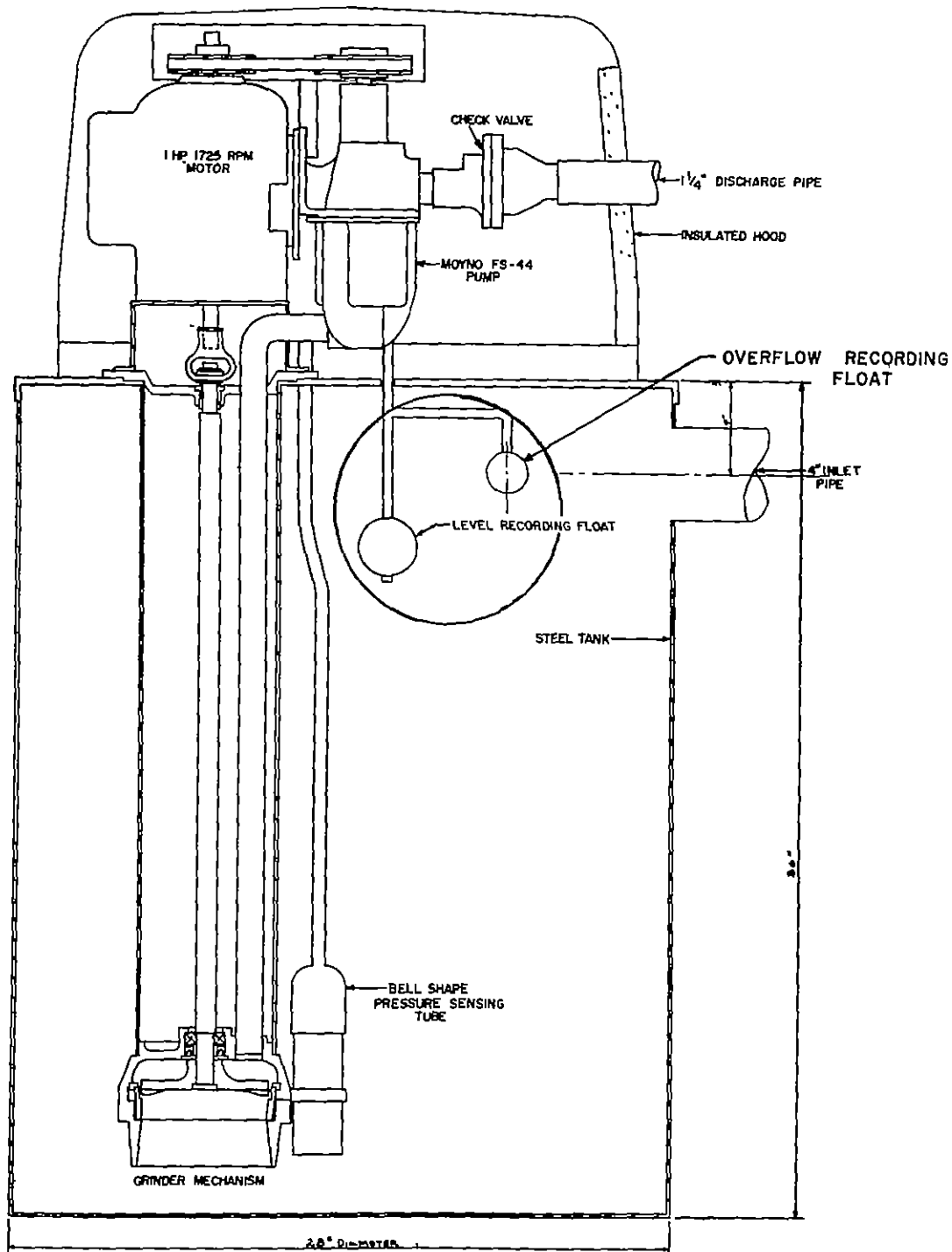
## Grinder-Pump Units

The GP Unit consists of the following mechanical components (Figure 2):  
(a) Grinder, placed in an inverted position and operating at 1725 ppm with the capability of handling foreign objects without jamming; (b) Pump, positive displacement, progressing cavity type with an almost vertical H-Q curve and proven

## FIGURE 1



**FIGURE 2**  
CROSS SECTION OF GP WITH LOCATION OF  
LEVEL AND OVERFLOW RECORDING FLOATS



solids handling ability; (c) Motor, 1.0 horsepower, operating at 1725 RPM, capacitor start, high torque, squirrel cage induction motor with a built-in thermal overload protector; (d) Check Valve, swing check type with passageways smooth and free from roughness and obstructions, and a unique flexible hinge of small section without mechanical pins, rivets, screws, etc; (e) Controls, an inverted diving bell system to turn the motor on and off.

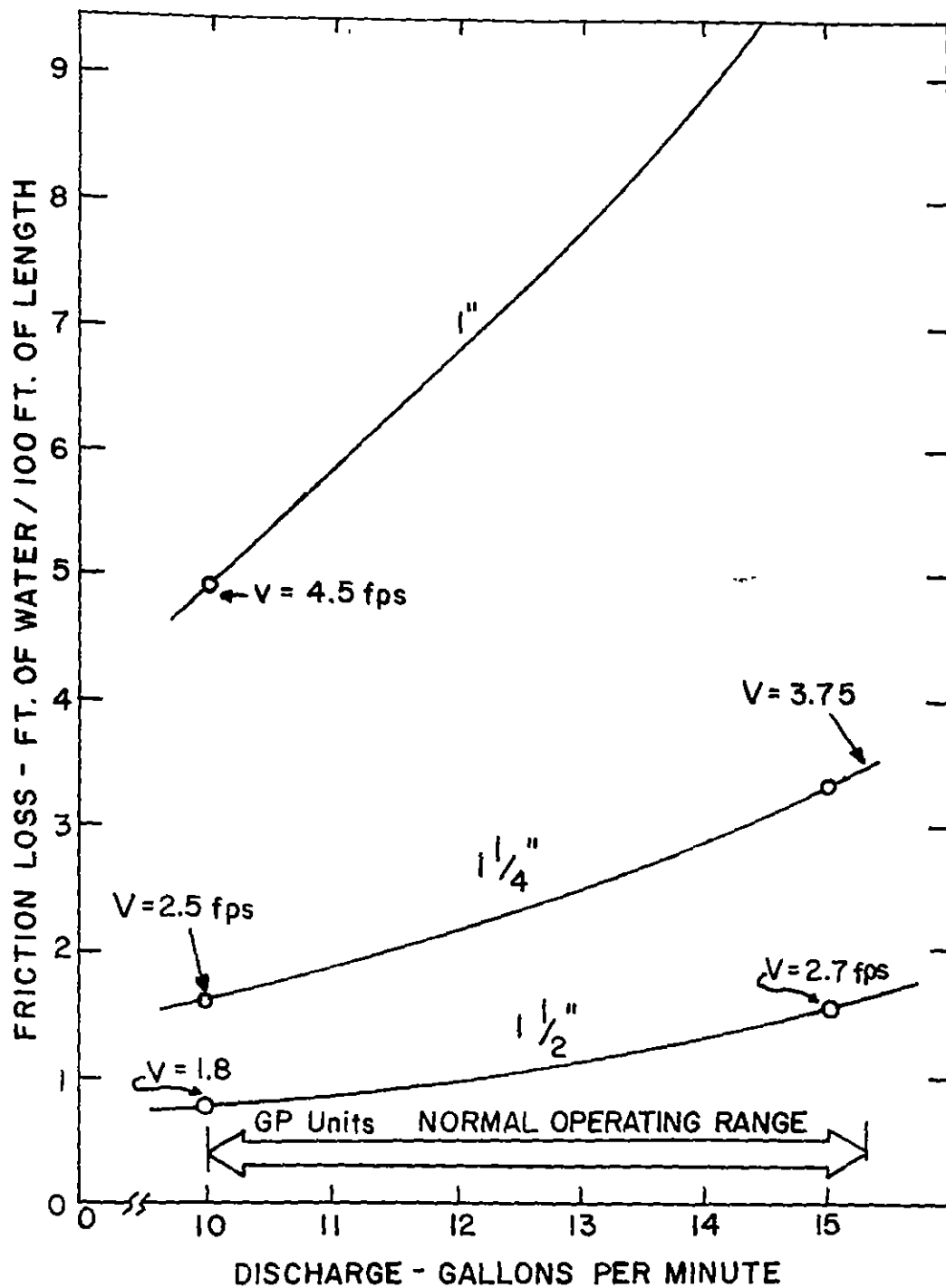
A  $1\frac{1}{4}$  inch discharge pipe was selected as the optimum size<sup>(3)</sup> capable of not only handling the macerated wastewater without clogging but also minimizing the frictional head losses (Figure 3).

### Results

Thirty nine out of the 44 recorded malfunctions were contributed by the Prototype GP Units. Nine of these Prototype units were replaced by Modified GP Units (Figure 4) after only 6 months because of the large number of malfunctions. The newer units performed satisfactorily for the remaining of the project. Loss of prime by pump and grease clogging of the 1" opening within the bell-shaped pressure sensing tube was the major cause of the malfunctions experienced by the Prototype Units. Corrective modifications were incorporated in the manufacturing of the modified GP Units with considerable improvements in the daily operation.

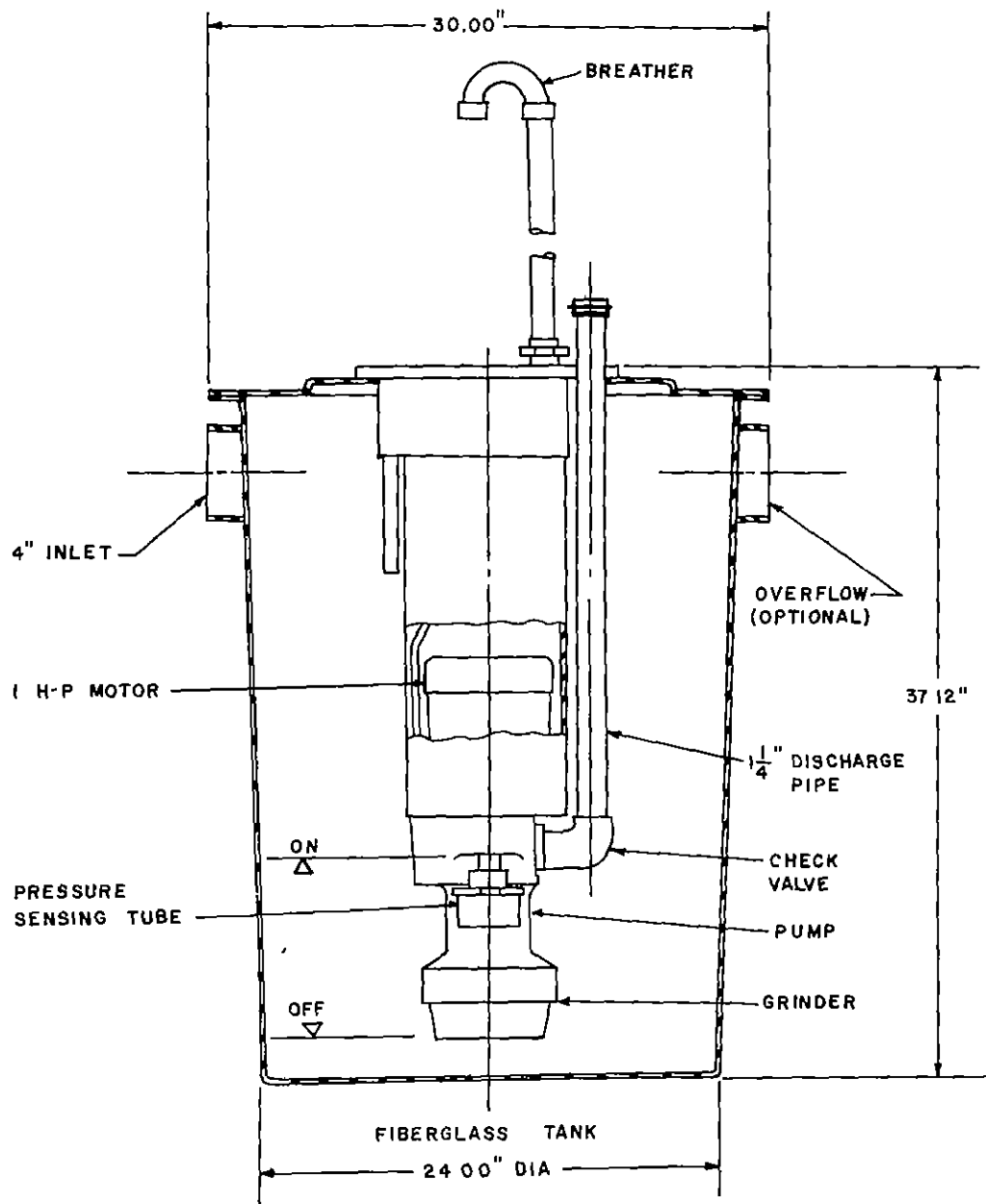
One of the primary interests of this project was to extensively test the reliability of the mechanical components in an actual field installation. Pre-installation testing and post-installation testing (Table 1) was performed in order to determine marked deterioration if any, in the physical structure and performance of the GP Unit's components.

In addition to the 6282 operations<sup>which</sup><sub>A</sub> occurred during the so-called



FRICION LOSS vs DISCHARGE  
FOR THREE SIZES OF  
POLYETHYENE PIPE

FIGURE 3



CROSS-SECTIONAL VIEW  
OF MODIFIED GP UNIT

FIGURE 4

Table 3 {  
SUMMARY OF OBSERVATIONS AND TESTS OF CRUISER PUMP UNITS AT CONCLUSION OF DEMONSTRATION

Item	1	2	3	4	5	6	7	8	9	10	11	12
Operations Counter Reading	11471	5211	11666	7214	5337	1707	6550	7057	9131	8694	3897	8225
M Hours	154	78	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Exam Controls for Moisture	OK	OK	OK	OK	OK	NA	NA	OK - Grease in Sensor	OK	NA	NA	OK
Timer Operations (Seconds)												
"On" Delay	35.0/36.3	35.7/35.4	33.9/34.8	32.6/33.0	42.1/41.4	NA	29.1/28.9	32.7/31.2	38.5/38.7	33.7/35.0	26.5/27.8	39.1/38.2
"On" Time	54.2/53.6	59.9/59.5	54.9/53.2	51.8/50.4	54.5/51.0	NA	50.6/52.5	71.1/66.5	50.0/49.3	35.7/40.0	31.4/29.3	48.7/48.3
"Off" Delay	30.5/29.6	26.0/25.5	27.2/26.5	26.6/25.9	25.4/24.2	NA	29.7/29.5	27.3/29.7	28.0/28.4	10.4/11.7	---/11.8	25.9/24.9
Check Valve Bubble Tight?	No	No	No	No	Yes	Yes	No	No	No	NA	NA	No
Noise Level	Quiet	Slightly Noisy (Loose Parts)	Quiet, but not as low as 1,5,9	Slightly louder than average	Quiet	NA	Louder than Model	Quiet, but something vibrating	Quieter than washer or furnace fan	NA	Very noisy (Boaring Problem)	Very quiet
Level Control												
Depth in Inches												
"On"	12 1/2	13	13	13-1/8	12	NA	14-1/8	15 1/2	13	10 1/2	9-3/4	12-1/2
"Off"	5 1/2	7	3 1/2	7	5 1/2	NA	7-1/8	4	5	4-3/8	5	5-1/8
Pump Performance												
GPM/Watts												
15 psig	14.8/900	14.7/875	14.8/850	14.8/850	14.8/940	14.8/925	14.2/860	14.8/900	15.2/875	15.4/900	14.8/860	14.8/850
25	13.8/1025	13.6/1000	13.6/1000	13.8/925	13.7/1050	13.8/1080	13.8/940	13.8/1025	14.0/1025	14.5/1000	14.0/960	NA
35	12.4/1125	12.2/1125	11.8/1075	12.5/1100	12.4/1100	12.2/1200	12.0/1060	12.4/1150	12.8/1160	13.4/1100	13.2/1060	12.3/1150

NA = Not Available, or not checked

de-bugging period, a total of 73,458 GP Units operations were recorded during the remainder of the demonstration project (Table 2).

Even though the operating cycle varied greatly for the prototype units, the modified units operated on a cycle between 57 and 74 seconds (Figure 5), with the average operating time of 11.5 minutes to 27.5 minutes per day. Furthermore, based on the occupancy rate of 75 persons for the 12 town houses, a value of 2.6 operating cycles per capita per day was calculated for this particular single family residential development.

The documentation of the operating cost was of prime interest, since it was essential to verify the theoretical cost value of \$2.12/year for a family of 5<sup>(3,4)</sup>. Two watt-hour meters were installed to register only the total power consumption of two individual GP Units. Based on the monthly operating time, proportional monthly power consumption values of 10.2 and 5.3 KW were calculated. Applying an average incremental power consumption rate of 2.3¢ per kilowatt hour (KWH), the monthly operational cost for Unit No. 1 amounted to \$0.24 and \$0.12 for Unit No. 2 (Figure 5), which is equivalent to \$1.18 for a family of 3, up to \$3.50 for a family of 9.

The GP Unit's usage varied greatly from day to day for any given unit. An even greater variation was documented when comparing weekday versus weekend usage. This is graphically illustrated in Figure 6 for two given units. The total weekend daily usage exceeded the weekday total daily usage by 50-60 operations (an increase of 35% over the weekday total).

As an indication of the improved performance record of Modified Units versus the Prototype Units, a value, known as the "down-time", was computed for each of the GP Units. The "down-time" value is based on the amount of time a unit was non-operational over the total amount of time of possible operation.

TABLE 2 - TOTAL NUMBER OF OPERATIONS

Unit No. Mo. Yr.	1	2	3	4	5	6	7	8	9	10	11	12	Total per Month
Oct. 70	1097	313	500	383	353	-	393	295	552	332	243	-	4,461
Nov. 70	753	283	509	342	369	-	372	347	575	303	242	-	4,095
Dec. 70	578	295	588	253	380	243	307	350	455	306	201	711	4,667
Jan. 71	993	279	925	456	381	214	359	338	466	250	191	777	5,629
Feb. 71	640	273	818	333	281	198	240	249	422	593	109	601	4,756
Mar. 71	523	264	972	599	299	290	282	701	546	592	124	933	6,125
Apr. 71	399	293	502	394	365	382	383	418	422	551	274	483	4,866
May 71	690	512	524	420	211	209	499	447	525	666	358	604	5,665
June 71	1154	444	493	313	401	-	440	571	577	719	284	600	5,996
July 71	993	483	539	288	295	-	559	828	530	686	370	666	6,237
Aug. 71	886	420	716	599	329	-	487	845	607	775	168	607	6,439
Sept 71	568	366	840	775	238	-	534	735	851	512	226	658	6,303
Oct. 71	950	523	842	761	428	-	814	516	840	500	-	602	6,776
Nov. 71	209	100	166	133	128	-	179	78	168	122	-	160	1,443
Total per Unit 10,433	4848	8934	8934	6049	4458	1535	5848	6718	7536	6906	2790	7402	73,458 Total

Average Operations = 2.6 per capita per day

**FIGURE 5**  
**SUMMARY OF OPERATIONAL DATA**  
**FOR MODIFIED AND PROTOTYPE GP UNITS**

	1*	2*	3*	4*	5*	6°	7°	8*	9*	10°	11°	12*
<b>OPERATIONS PER DAY</b>	28	15	21	17	10	10	15	22	22	18	8	21
<b>LENGTH OF OPERATING CYCLE (SEC.)</b>	59	71	74	59	69	65	55	57	67	39	40	68
<b>TOTAL OPERATING TIME PER DAY (MIN.)</b>	27.5	17.8	25.9	16.7	11.5	10.8	13.7	20.9	24.6	11.7	5.3	23.8
<b>POWER CONSUMPTION COST PER MONTH (\$)</b>	0.24	0.12	0.27	0.17	0.12	0.12	0.14	0.21	0.25	0.12	0.10	0.24

\* Modified GP Units

° Prototype GP Units

°° Unit #6 became vacant after May 18, 1971.

Values are based on Prototype GP Operations

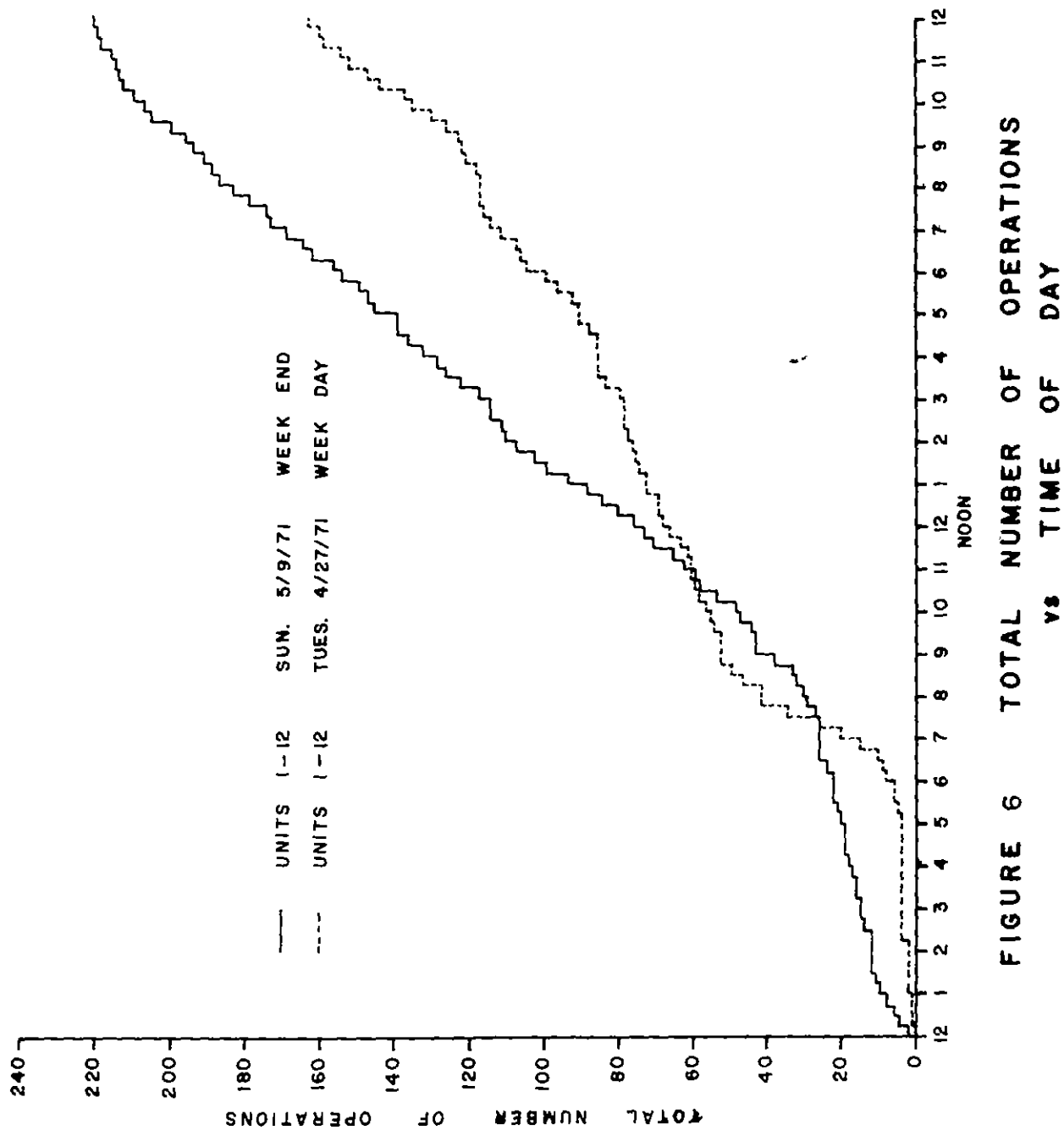


FIGURE 6 TOTAL NUMBER OF OPERATIONS  
vs TIME OF DAY

The Prototype GP Units produced a "down-time" of 2.69% for the first six months in comparison to only 0.27% for the Modified Units over the last 7½ month period.

### Discussion

The pressure sewer system pipe sizing was based on the ASCE minimum scouring velocity criteria of  $V_s = \frac{d^{(5,6)}}{2}$  and on certain engineering assumptions regarding the estimated wastewater flows from the 12 GP Units.

It must be understood that the flows in the different portions of the pressure main were based strictly on an engineering estimate. There was no data available on the frequency of GP operations for a multiple units system. It was possible to predict the peak usage hours of the GP Units, but since the operating cycle per GP Unit is very small, 57 secs. to 74 secs., it was almost impossible to predict the number of units working simultaneously during this peak period. It was, therefore, assumed that a maximum flow of 90 gpm would flush regularly that portion of the pressure main serving all 12 GP Units. It must be understood that the hydraulic characteristics of the pressure sewer system is dependent greatly on the varying wastewater flows within that system.

Information on simultaneous occurrences was an essential phase of the project. This type of data is critical for the design of future pressure sewer systems. The maximum anticipated flows will dictate the size of pipe within the pressure system. At the same time, the hydraulic gradient will reach its peak slope. The engineer, therefore, must design a system optimizing the sizes and scouring velocities and be certain that the upper recommended working pressure of the GP Unit is not exceeded.

During the last ten (10) months of the demonstration project, during which time the 12 channel event recorder was in operation, a total of 58,823

operations were recorded, which represent approximately 191 operations per day. Therefore, in order to obtain a picture of the minimum and maximum flows within the pressure system, the above mentioned data indicated that (a) on the average, 2 GP units ran simultaneously 20 times per day (b) 3 GP units operated simultaneously slightly more than once per day, and (c) 4 GP units ran simultaneously on the average of once every 14 days.

Also, by using all the automatically recorded data, total wastewater flows were calculated, which ranged between 95 and 100 percent of the actual water consumption (Figure 7).

The close relationship between the water and calculated wastewater flow is a highly reliable indicator of the corresponding wastewater discharges. Also, winter water flow records can be used to estimate accurately expected wastewater flows.

Pressure gages were installed in each basement so that the maximum and minimum pressures occurring during any fifteen minute period might be recorded. These pressure readings were indicative of the varying hydraulic gradient line for each of the twelve GP units (Figure 8). The computerized data indicate that pressures in excess of 30 psi were reached by a few GP Units.

Once the demonstration phase of the project was completed, portions of the pressure main and the  $1\frac{1}{4}$  in. pressure laterals were carefully excavated and removed. Grease accumulation within most sections was evident. Reductions of up to 40% occurred in the pressure main.

The system was simply oversized. Where flows were expected to reach 90 gpm regularly, flows of only 45 gpm were recorded (Figure 9). Therefore, instead of a 3" pressure main, a 2" main would have been sufficient for the 12 town houses.

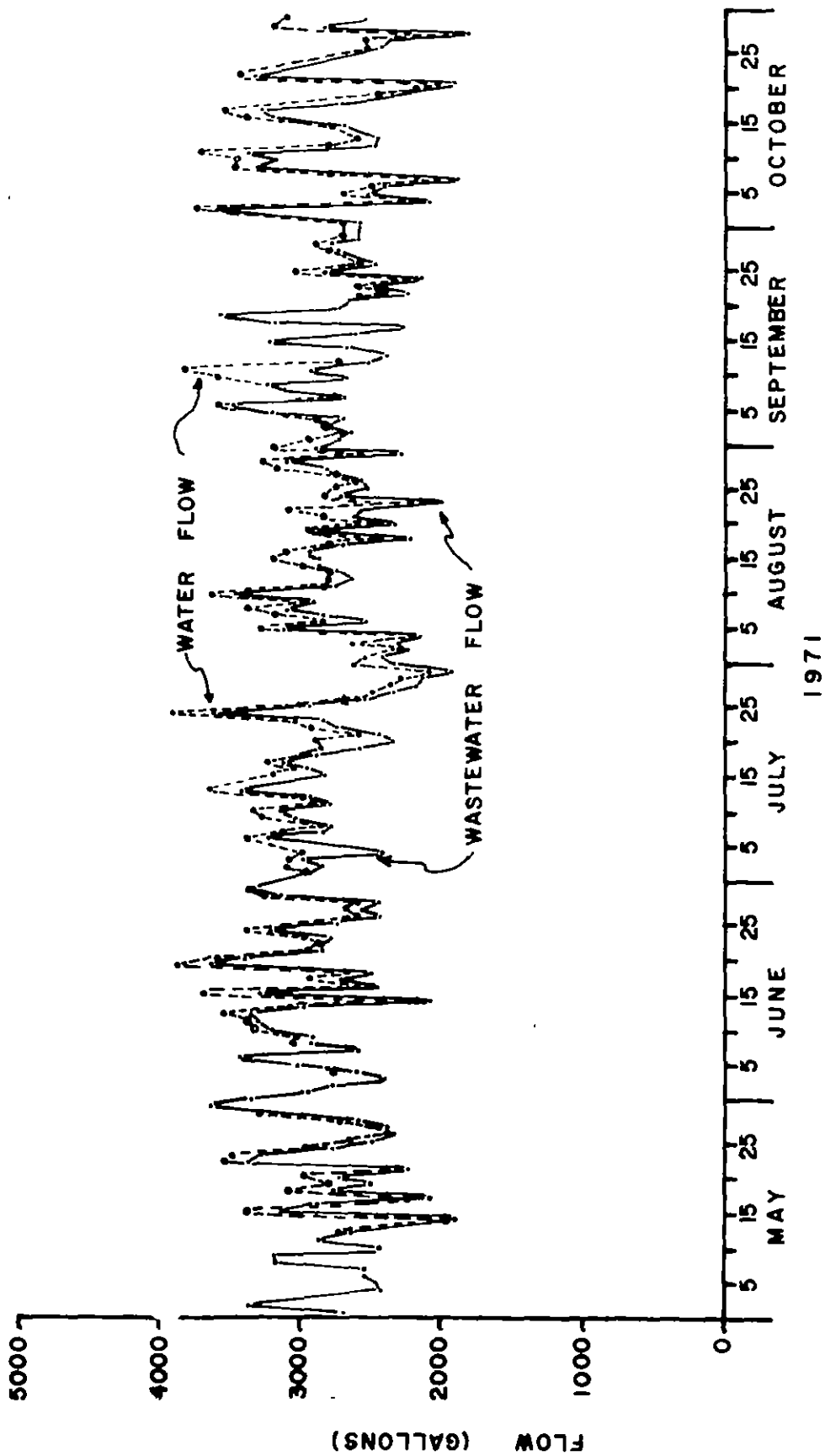


FIGURE 7 WASTEWATER AND WATER FLOWS